6 LEVEL II

December 1981

TECHNICAL REPORT TR 81-12-312.43

A Friendly Personal Decision Aid

Scott Barclay
Robert M. Esoda
Cynthia [illegible] Cox
Cameron R. Peterson
Jonathan J. Weiss

DECISIONS and DESIGNS, INC

Prepared for

TECHNICAL REPORT TR 81-12-312.43

A FRIENDLY PERSONAL DECISION AID

by

Scott Barclay, Robert M. Esoda, Cynthia [illegible] Cox, Cameron R. Peterson, and Jonathan J. Weiss

Prepared for

Defense Advanced Research Projects Agency
Defense Sciences Office
System Sciences Division
1400 Wilson Boulevard
Arlington, Virginia 22209
Contract MDA903-80-C-0194
DARPA Order No. 3831

December 1981

DECISIONS AND DESIGNS, INC.
Suite 600, 8400 Westpark Drive
P. O. Box 907
McLean, Virginia 22101
(703) 821-2828

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TR 81-12-312.43	2. GOVT ACCESSION NO. AD-A109 130	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) A FRIENDLY PERSONAL DECISION AID		5. TYPE OF REPORT & PERIOD COVERED Technical Report 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Scott Barclay, Cameron R. Peterson, Robert M. Esoda, Jonathan J. Weiss, Cynthia L. Cox		8. CONTRACT OR GRANT NUMBER(s) MDA903-80-C-0194
9. PERFORMING ORGANIZATION NAME AND ADDRESS Decisions and Designs, Inc. Suite 600, 8400 Westpark Drive, P.O. Box 907 McLean, VA 22101		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DARPA Order No. 3831
11. CONTROLLING OFFICE NAME AND ADDRESS Defense Advanced Research Projects Agency (DARPA) Defense Sciences Office, System Sciences Division 1400 Wilson Boulevard, Arlington, VA 22209		12. REPORT DATE December 1981 13. NUMBER OF PAGES 27
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Decision theory
Decision analysis
Decision aids
Computer-aided analysis
Computer-based modelling
Decision making models

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Early efforts to produce decision aids, although they led to valuable research findings, did not succeed as field applications. Even when the targeted users agreed that the computer-aided decision process did improve decision making, these aids eventually fell into disuse when the personal support of the decision analysts was removed. User attitudes tended to be dominated by the short-range considerations of speed, convenience, and simplicity of operation, rather than by the long-range factors such as methodological thoroughness and consistency.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

The primary goal of this research project, sponsored by the Defense Advanced Research Projects Agency (DARPA), was to develop a prototype version of a user-friendly decision aid which could be used by persons with little or no prior training. This decision aid was not only designed to be easy to use, but also to save time and fit into the user's office or field site, while still providing the benefits of a technically sound decision-analytic approach. Since then, a prototype system has been developed, and a working model has been delivered to DARPA. This report is intended to accompany that working model. Its function is to document the purpose of the research effort, the technical approach, accomplishments of the project, and the prognosis for future development based on lessons learned during the effort. Because of the aid's self-explanatory nature and its unique hardware configuration, neither a users guide nor a system manual is needed.

TABLE OF CONTENTS

1.0 INTRODUCTION

This Final Report describes the results of work performed by Decisions and Designs, Inc. (DDI) under DARPA contract number MDA903-80-C-0194. The goal of this contract was to develop a prototype version of a user-friendly decision aid which could be used by persons with little or no prior training. A prototype system has been developed, and a working model has been delivered to DARPA; this report is intended to accompany that working model. Its function is to document the purpose of the research effort, the technical approach, accomplishments of the project, and the prognosis for future development based on lessons learned during the effort. Because of the aid's self-explanatory nature and its unique hardware configuration, neither a users guide nor a system manual is needed. Furthermore, no attempt is made to describe the details of the aid's functions and displays, except insofar as that information reflects higher-order technical issues.

1.1 Objectives

The motivation for research and development of a Friendly Decision Aid stems from two historical trends. On the one hand, the mathematical techniques of Decision Analysis have, during the past decade, achieved a high degree of technical sophistication; this growth reflects not only the success of a long-term research effort sponsored by DARPA and several other government agencies, but also the practical experience gained through myriad applications by decision-analytic firms such as DDI. At the same time, the very success of the decision-analytic techniques has led to a demand for applications in a very different environment: instead of depending on a specially trained decision analyst, some decision makers would prefer to acquire a computer-based decision aid which could operate successfully without the continuous need for a professional analyst.

Early efforts to produce decision aids, although they led to valuable research findings, did not succeed as field applications. Even when the targeted users agreed that the computer-aided decision process did improve decision making, these aids eventually fell into disuse when the personal support of the decision analysts was removed. Among the many hypotheses to explain this phenomenon, the following appeared to provide the most powerful explanation:

> In the absence of strong external motivation, the general user will prefer a computer-aided decision process only if it is perceived as a convenient way of saving time and effort.

In other words, user attitudes tend to be dominated by the short-range considerations of speed, convenience, and simplicity of operation, rather than by the more qualitative factors like methodological thoroughness and consistency, or hard-to-see impacts such as a tendency to make better choices with the decision aid.

DDI undertook this project to demonstrate and test this hypothesis. The purpose is to (1) produce an aid which would be pleasurable rather than painful to operate; (2) save rather than consume time; and (3) fit into the user's office or field site, while still providing the benefits of a technically sound decision-analytic approach. In particular, these criteria were specified:

- The aid should be small enough to fit comfortably into an office, and should require no special installation procedures.

- It should be simple to operate, and not require users manuals or training.

- It should provide self-contained instruction for the novice user, while permitting the more experienced user to bypass unnecessary explanatory material.

- User inputs should be simple, rapid, and convenient; in particular, the need to type inputs should be minimized.

- As far as possible, user-machine interactions should avoid methodology and specialized technical vocabulary.

- It should be possible for the user to request help, to terminate a session, or to discontinue a session temporarily and resume later, at any point during the analysis.

- Results should be presented to the user in a simple, visually appealing format, using graphics wherever possible, in preference to text or numbers.

- A library of prepared analytic models should be available for users at all levels of experience to apply in a variety of problem areas.

- It should be possible for a more experienced user to construct new models to apply to arbitrary *ad hoc* problems.

- The hardware configuration of the system should be producible in large quantities at a low unit cost ($25,000 would be an upper bound).

1.2 Summary

The remainder of this report describes DDI's efforts to achieve the objectives listed in Section 1.1. It also describes the degree of success attained, and the lessons learned from the effort. Section 2.0 describes the technical approach DDI used, including the decision-analytic methods, user-engineering approach, and system configuration. In Section 3.0, the decision aid product is evaluated with respect to the criteria listed in Section 1.1. Section 4.0 summarizes the lessons learned during the process of research and development. Finally, Section 5.0 contains recommendations for further development and improvement, and for transfer to users in the field.

2.0 TECHNICAL APPROACH

The decision-analytic approach of the Friendly Decision Aid is described in detail in Section 2.1. Briefly, it is a variant of the EVAL/HIVAL approach to Multi-Attribute Utility Analysis, with a simplified procedure for eliciting the quantitative input values and for displaying results. Decision templates provide the user with a library of previously developed model structures; in addition, the experienced user can also use the aid to construct new models for ad hoc problems.

While the decision-analytic techniques used are fairly standard, the efforts at user-friendly interaction represent a new and unique approach. Section 2.2 describes the psychological basis for the aid's interactive features, while Section 2.3 summarizes the system's overall configuration.

2.1 Decision-Analytic Approach

2.1.1 Multi-Attribute Utility Analysis - The EVAL/HIVAL methodology was selected for several reasons. It involves scoring each of the alternative options on several fundamental criteria, and then weighting each of the criteria. For simplicity and transparency, criteria may be grouped hierarchically into superordinate categories, with a manageable number of subordinate criteria (two to four) per category. Since the evaluation model is a linear combination, it is robust mathematically, and thus is ordinarily not sensitive to small changes in the input values. In addition, the associated model is easy to describe, and does not require the understanding of probability theory.

The elicitation of option scores in a HIVAL model is generally a straightforward process. Taking each criterion separately, the user is first asked to select the best and the

worst option with respect to a criterion. Then, the remaining options are rated on a scale between the two extremes. While most previous decision aids have used a numerical scale (e.g., 0 to 100 points) for this elicitation, the Friendly Decision Aid displays a linear scale graphically and interacts with the user in terms of the location of points along that scale (retaining the numerical equivalents internally); the user never needs to specify inputs numerically or to interpret numerical outputs.

More difficulty is typically associated with the assessment of weights for the criteria. This step involves a more complex judgment: the decision maker is asked to judge the relative importance of the <u>difference</u> between the best and the worst options on one criterion, as compared with the <u>difference</u> between best and worst on another scale. Because it requires the decision maker to consider several quantities simultaneously while making critical value judgments, this step is difficult to describe simply. For this reason, and because of the task's unfamiliarity and inherent complexity, this step is the most frequent source of major errors in the assessment process.

The solution implemented in the Friendly Decision Aid is to ask the user for a series of simpler judgments, involving a simple ranking of criteria, and inferring from the rank-ordering judgments the implied set of criterion weights. This general type of procedure is known as <u>conjoint measurement</u> and has a large body of psychological and mathematical research behind it. In the Friendly Decision Aid, after the options have been scored, the aid presents those criteria on which a given option ("Option A") was preferred to another ("Option B"). The user rank orders those criteria according to the magnitude of the preference for Option A over Option B. From a series of such rank orderings,

the aid calculates a complete set of weights consistent with the user's judgments.

2.1.2 Decision Templates - Certain decision problems can be partially anticipated. For instance, although the specific options and their values may not be known in advance, the evaluation criteria and structure can be developed and stored for more rapid use when a specific decision is required. These problems fall into three general categories:

- Familiar problems which may occur for a large population of decision makers who will tend to use the same general set of criteria with only minor variations (e.g., buying a car, or choosing a vacation site).

- Recurring problems, where the same user routinely faces the same type of decision problem often enough to adopt a standardized approach (e.g., preparation of personnel evaluations).

- Anticipated crises, where the critical need for a rapid response places a premium on analysis in advance of the actual crisis (e.g., preparation for an enemy attack).

In such situations, it is advantageous for the decision maker to have access to a previously developed model structure which can be completed simply by specifying options, and assessing scores and weights. These structures, or Decision Templates, help the Friendly Decision Aid to minimize the impact of model structuring which can be the most time-consuming and risky phase of decision analysis. By providing a library of templates for general users, the Friendly Decision Aid permits even a novice user to perform a limited range of decision

analyses without difficulty. Also, by permitting the more sophisticated user to build and store new templates, the aid helps the decision maker to allocate time more effectively.

2.1.3 Decision-analytic expertise - In conducting an applied decision analysis, the professionally trained analyst does not adhere to a rigid, linear sequence of steps. The experienced analyst knows when to examine an issue in more detail and when a rough approximation will suffice; he recognizes when and how to apply alternative elicitation techniques, and how to minimize possible biases in judgments; and he knows when and how to revise the structure of a developing model as new information appears. To incorporate such procedural knowledge in a computer-based aid would greatly improve its value, particularly in guiding the construction of new models. While the overall approach of the Friendly Decision Aid would lend itself to the creation of such a "smart" aid, only the simplest of approaches have been implemented in the current version.

2.2 Psychological Approach

The following design goals are based on research findings in behavioral, cognitive, and human factors psychology. Combined with the simple decision-analytic approach discussed in the preceding section, they form the basis for DDI's approach to the Friendly Aid.

- Easy access - Because the most immediate consequences have the strongest influence on behavior, the user should have no difficulty in starting up the system, and no prior training should be necessary.

- Simple controls - To minimize user error and effort, controls should be simple and direct; in particular, the need for entering text via a typewriter keyboard

should be minimized. Also, wherever possible, the user should be presented with a limited set of well-defined choices, rather than required to know what options are available.

- <u>Sensorimotor feedback</u> - To maintain a reliable link for user-machine communication, user inputs should be immediately acknowledged by a perceptible (but non-disruptive) signal from the aid; in the event of an "illegal" user response, the aid should let the user know quickly, allowing the user to correct the response without disrupting the aid's ability to function.

- <u>Response timing</u> - Ideally, the aid should perform all of its functions quickly so the user never has to wait more than a few seconds for a response. If a delay of more than 30 seconds is inevitable, however, the aid should warn the user and, if possible, indicate how long a delay to expect.

- <u>Adaptation to individual users</u> - To make the aid more compatible with each user's personal preferences and behavior patterns, the aid should "customize" its functions: fast/slow tracking should permit the more experienced user to bypass things like tutorial material, which the novice would find useful; user preferences for modes of input and output should be accommodated as well.

- <u>Aesthetics</u> - The aid should be aesthetically attractive to the user. It should be packaged in a secure, sturdy, neat-looking cabinet which can fit unobtrusively into an office.

2.3 System Configuration

The actual configuration of the DDI Friendly Decision Aid consists of an Apple II personal computer, augmented by a 10 Mb hard disk. All input and output functions take place on a color video monitor with a superimposed transparent touch-sensitive screen. Because the user interacts only with this touch-screen display, the other components have been enclosed in a cabinet which not only simplifies the system's appearance, but also enhances portability and reduces the risk of accidental damage. The system is arranged so that the monitor's on/off switch automatically sequences all hardware components and triggers sign-on and sign-off routines; no "log-in" or "log-off" procedures need to be learned, and there is no need in normal operation to see or touch any of the components within the cabinet.

While the aid is functioning, the user enters information by touching areas on the screen. A number of formats for this interaction are used during the aid's operation. For example, control functions are selected from push-button-like squares at the bottom of the display. Selection of items from a list (e.g., in response to a question such as, "which of these options is best on this factor?") takes place when the user touches the chosen item on the screen. (A short immediate "beep" alerts the user that his response has been accepted; if the user has touched an "illegal" section of the screen, a longer, lower-pitched sound warns the user to reenter the response.) Although the use of restricted-choice menus avoids most of the need for free text input, the display of a typewriter keyboard (with the characters either in alphabetical order or in the normal typewriter configuration) is available on which the user can "type" by touching the areas on the screen corresponding to the desired "keys".

The aid's software permits the user to identify himself and to specify certain personal preferences which are then maintained in a user profile. For example, the user may record a preference for the alphabetical keyboard display versus the typewriter configuration. In addition, the user profile includes information about the user's level of experience on the system ("novice" versus "fast track"), and a library of templates and user-constructed models.

3.0 PRODUCT EVALUATION

The DDI Friendly Decision Aid, as realized in the prototype version constructed under the present contract, demonstrates several positive features, some for the first time on any functional decision-aiding system. In general, the responses of pilot users have been positive, although no formal user evaluation has been attempted to date. A few negative observations have been noted, however, which are related to the specific hardware chosen for the prototype system (particularly the use of the Apple II computer). Furthermore, some absent capabilities were identified as desirable additions to any subsequent version. Finally, a number of features which were part of the original plan could not be sufficiently developed during the span of the contract to permit implementation and testing.

3.1 Good Features

3.1.1 Analytic approach - By restricting the judgments required of the user to simple ordinal rankings, and by avoiding the need for numerical assessments entirely, the Friendly Decision Aid overcomes perhaps the most significant objection of untrained decision makers: their perceived inability to quantify subjective judgments. In addition, because results are depicted graphically rather than numerically, the effort, delay, and risk of error associated with interpreting those results is substantially reduced.

3.1.2 User-machine interaction - The simplified interaction using the touch-screen display for all inputs and outputs was very successful. It reduced response effort to a minimum, while permitting the user to focus attention on a single control area (rather than shifting attention from a display screen to a keyboard, a printer, a diskette drive,

etc.). The immediate audio feedback ("beep") accompanying each touch-screen entry helped to maintain user confidence and, consequently, to permit faster operation with less need for checking entries.

The use of color, while not absolutely essential to the aid's functioning, was extremely valuable from a motivational and from a human factors standpoint. The multi-colored displays added visual stimulation and variety to the user environment. Furthermore, it made the graphical displays easy to read, and permitted the use of color-coding to identify groups of items belonging to the same category.

Another display-related feature which served both motivational and human-factors goals was the use of simple graphic displays on which changes could be represented as apparent motion. For example, a change in one or more of the options' scores would appear on the display as the movement of the corresponding colored dots. If a weight was changed, the implied change in overall scores would appear as the growth or shrinkage of the bars which represent those scores. This motion, especially with a rapid response, made the aid more interesting to operate, while making the results of any changes easy to visualize.

3.2 Bad Features

Most of the undesirable features associated with the Friendly Decision Aid could be traced to the use of the Apple II personal computer as a central processing unit. Originally purchased because of its low basic cost and wide-spread availability, the Apple II appeared to be the best of the "personal" microcomputers available commercially at the onset of the contract. However, the low price turned out to be somewhat

deceptive, as peripheral devices had to be added to augment the basic system's capabilities to support the aid's functions.

The Apple II processor itself was designed as a hobbyist's computer, and lacks the size, speed, flexibility, and features that a professional application would require. Its memory limitations impose constraints both on the system's capability and on the design and programming processes. Its operation using the Pascal language was often so slow that important routines had to be rewritten when a timely result rather than a slower, but more correct one was required; options for faster languages were limited, and on one routine, even a recoding in assembly language failed to improve time performance. Finally, the Apple II graphics (and particularly the alphanumeric character set) were unwieldy, producing irregular coloration and poor legibility; this necessitated additional efforts to correct the resulting display problems (e.g., the construction of a new, more legible, character set).

A related problem which was an outgrowth of the hardware configuration was the excessive bulk of the entire system. A more compact, integrated unit in a smaller cabinet would have been possible, given a different choice of hardware.

In the decision aid itself, the only major shortcoming was the lack of a "road map" to answer the user's "where am I?" questions. Occasionally, during the course of an analysis or upon resuming a previously interrupted analysis, the user needs to be reminded of his current stage and how much remains to be done. Alternatively, the user may be focusing on one portion of an analytic model, and wish to see where it appears in the context of the entire model. Demands for a display of the entire model or the entire procedural context, without disrupting the flow of the analysis, are currently unmet. Other than inherent limitations on the size of the display, there should

be no obstacle to adding an optional "where am I" feature to the current system.

3.3 Untested Features

Three elements of the originally planned design were not sufficiently developed during the research effort to permit their implementation, testing, and evaluation. The first -- voice input and output -- was begun using a speech recognizer for input of keywords (with a limited vocabulary of words) and a speech synthesizer for output of verbal material. Although some initial success was achieved, the memory requirements precluded its use in the final version. Ultimately, more effort will be needed to incorporate a reliable speech input/output facility into the decision aid.

A second feature which was not implemented during this initial effort was an instruction capability, in which the aid would explain every step of the analysis to the naive user by displaying an exemplary session with a hypothetical user. Partly because the aid functions so simply, and partly because a "help" feature would provide needed information on demand, the instructional capability was not a high-priority item.

A more desirable feature, but one which might require a substantial effort to implement satisfactorily, would be to add sufficient "intelligence" to guide the analytic process. Incorporating some of the procedural practices and heuristics of the experienced decision analyst, such a routine could streamline the analysis, and at the same time, produce more compelling results. At present, no existing system demonstrates a successful capability of this sort, so the potential benefit of a success would be great.

4.0 LESSONS LEARNED

This section presents a brief summary of several lessons learned during the course of this research effort. Some of those lessons refer to the functional properties of decision aid systems, some to specific experiences with respect to the selection and purchase of hardware components, and some to the design process itself.

4.1 Functional Properties

The major lesson learned from this effort was that a simple, user-friendly system on a small computer is a feasible undertaking. The use of simplified input/output via the touch-screen display was very successful, as was the use of color and simple auditory feedback to maintain user attention and motivation. While the use of speech to augment the visual displays was not fully tested, it appears to be a desirable direction for continued research.

In terms of the analysis itself, the use of templates to provide a general-purpose library for the user made it possible for even the novice user to perform a complete analysis fairly quickly. The non-numerical assessment and display techniques (ordinal judgments, graphic displays, and motion to represent change) worked successfully, and deserve more widespread application in decision aids.

Although the current effort did not attempt to implement a dialogue system in which the aid explains both the decision-analytic theory and specific procedures to the user, experience with the current system suggests that such a system might not be necessary, and indeed that extensive dialogue might even be undesirable. In the first place, a similar informative capability could be achieved by extensive use of the "help" button

feature which would make supplementary information available without any penalty to the user who does not need that information, or who cannot spare the time. Furthermore, the success of the simplified analytic procedures in the current aid makes the need for such explanatory material far less critical than it would be if more complex, sensitive judgments were desired.

4.2 Hardware Experience

The primary lesson learned from the present research and development experience is that a professional quality decision-aiding system requires more sophistication than the Apple II or a similar home computer can ordinarily provide. The option of adding on peripheral devices to augment its capability is expensive enough to negate the original cost and size advantages, and even with substantial additional effort, cannot match the capabilities of some larger, only slightly more expensive microcomputers. In a market where hardware costs in general are dropping, and labor and software costs are rising, a more capable processor should be worth the additional initial investment.

Considerations which should influence the choice of a central processor include physical size, memory capacity, peripheral (disk) speed and capacity, and overall reliability and service. In addition, the following factors are critical:

- Good-quality graphics, including an easily legible type font;

- Input/output compatibility with color video monitors (RGB and STSC), as well as large-screen video projectors; and

- Ability to perform calculations rapidly, without disrupting display or control functions.

Another hardware-related lesson learned during this effort was that, at least at present, microprocessor hardware delivery is routinely subject to delays of up to about four weeks. In addition, personal computer vendors routinely offer equipment which is not yet available, in an attempt to gauge market response. The limitations and idiosyncrasies of much microprocessor hardware can also cause further delays due to programming difficulties because non-standard techniques must be used to save space or time. This programming delay is compounded by the limited selection of high-level programming languages on some microcomputers.

4.3 The Design Process

The experience of this and previous efforts at designing, implementing and evaluating computer-based decision aids suggests that the design of a complex interactive system such as a decision aid should be an evolutionary process. The "linear" approach in which specifications are determined by the analyst and are passed on to computer scientists who try to meet those specifications is not only inefficient, but it also runs the risk of producing a useless product. This may occur because minor flaws in the specifications or their communication may drive the development in the wrong direction. The evolutionary approach, on the other hand, involves a less structured, iterative process in which there is ample opportunity for the analyst/designer or the target user to intervene before significant resources are committed. Ideally, the system should be as flexible as possible during the development process, even if this flexibility involves moderate sacrifices in cost, speed, or size; only after a final design has been implemented, tested, and accepted, should efforts be specifically directed to improving efficiency.

For a decision aid such as the Friendly Decision Aid, the implications of this design philosophy would suggest that, in the future, similar aids be initially developed on a large, fast, flexible system, using a high-level, easily modifiable language (such as APL). On such a system, the designers would be able to attend to effectiveness, without the unnecessary inconvenience and delays involved in conforming to a more restrictive environment. Iterative testing and improvement, or major redesigns, could take place in parallel on a modular basis, with the option of assigning different "experts" to different subtasks.

With proper precautions, the final form of the aid could be transferred satisfactorily to the actual system on which the aid will operate. Even if this transfer involves recoding in a different language or adaptations for different hardware, the total time required for the development effort, the manpower and development cost, and the quality of the final product should all improve. The evolutionary process as described here allows productive development to take place according to plan, even if delays in delivery or service problems make the system hardware temporarily unavailable. Because of increased flexibility in making hardware changes (e.g., in response to new information or new products), risk of premature commitment to a particular item or vendor is further reduced.

5.0 RECOMMENDATIONS

The research efforts described in this report have resulted in a convincing demonstration that a computer-based decision aid can be designed for effective use in the absence of a decision analyst. The prototype system which this report accompanies represents a major advance in terms of the criteria for a successful decision aid. However, there are many directions for continued growth and development. This section summarizes a few recommended directions for future research and development.

5.1 Hardware Improvements

During its initial investigations, DDI detected a number of features in the hardware design of the Apple II computer which severely limit the capabilities of Apple-based decision aids. Particularly significant are the limits on color graphic display and the lack of input/output buffering. Because of the way Apple implements its color graphics, only six colors are available, and these cannot be mixed freely on the screen. In particular, true colored alphanumeric characters are not possible, and ordinary white characters are displayed with random tints of colors. Because displays are limited to only 40 characters per line, it is often necessary to abbreviate labels (for options and criteria), an undesirable feature from the user's point of view. Furthermore, the color signal from the Apple contains extraneous noise which causes graphics to be blurred. Finally, the lack of input/output buffering means that the execution of the decision-analytic routines must halt while program segments or audio output phrase tables are being loaded into computer memory.

While it would be premature to specify a unique configuration for replacement hardware, a number of attractive alternatives have been identified and approximate costs assessed.

With the intended changes in hardware (consisting primarily of a different central processor and graphics display), the new prototype systems should cost approximately $25,000 per unit. However, $5000 can be saved by reusing components of the original systems, with substantial cost reductions when produced in quantity.

The transfer of the current decision-aid software to the new configuration will necessarily involve a moderate amount of technical labor in addition to the hardware itself. However, if the new system is implemented using the same higher-order language (Pascal), labor costs should be minimized.

5.2 Full-Scale Instruction Capability

As originally conceived, the Friendly Decision Aid was intended to provide an instruction capability so that any decision maker, even one who had never heard of decision analysis before, could use and understand the aid. In order to provide such a capability without unnecessarily slowing down or boring the more experienced user, a "slow/fast track" feature was designed into the system. A slow-track user would receive more explicit directions and assistance; the fast track, on the other hand, uses abbreviations and interactive routines to permit faster and more convenient operation.

While the original decision aid provides some instruction and some assistance via a "help" option, it currently permits the novice user to construct decision models only by using the pre-developed templates in its memory; only fast-track users can create completely new templates. One of the goals of the proposed project will be to extend this template-building capability to the slow track, while providing more extensive and more useful instruction and guidance.

5.3 "Smart" Decision Aid

The current Friendly Decision Aid is helpful in guiding the decision maker through a standard sequence of steps in the decision analysis process. Although the overall process is highly responsive to the user's directions, it lacks the intuitive ability to perceive patterns in the user's responses which might indicate the need for alternative elicitation techniques, or the possibility of time-saving simplifications. A further advantage could be achieved from the capability to help the user explore the decision-analytic model in an attempt to detect underlying patterns in the data; this would aid the decision maker's understanding of the problem, and help to identify and reconcile possible inconsistencies.

The task of implementing a "smart aid" feature should be extremely challenging, as it requires the most sensitive and adaptive aspects of the decision analyst's relation to the decision maker. The effort will involve several components: descriptive behavioral and perceptual studies of the model exploration process; design and implementation of a more sophisticated user-machine dialogue process; and the development and coding of algorithms to be used as heuristic guides to model exploration.

Although the task is ambitious, the potential benefits of a "smart" decision aid would be great. Under severe time constraints, the user could advise the aid to look for shortcuts without seriously compromising technical validity. On the other hand, the user with more time could use the model exploration feature to improve the model's validity, credibility, and usefulness, and to develop a more compelling summary of the data in the model.

5.4 Formal Testing and Evaluation

In addition to the pilot testing which is a necessary part of the development effort, it would be valuable to submit the Friendly Decision Aid to a more formal testing and evaluation study. A structured set of pre-determined performance criteria could be constructed, including objective measures such as system response times, behavioral observations such as user error rates, and subjective evaluations such as user confidence ratings. Using these criteria as an evaluation structure, the aid could be tested using realistic problems for which a "correct" solution could be determined by experts, and a population of subjects similar to the class of decision makers for whom the aid is intended. The aid could be evaluated with respect to "absolute" criteria (such as user expectations), or in comparison to unaided approaches or to other decisions aids.

One clear value of a formal test and evaluation study would be the ability to document the aid's performance for a large audience of potential users, through journal publications and other public media. In addition to its potential contribution to the technology transfer process, a formal study would also contribute to further development and refinement by generating an extensive list of comments and suggestions, and would produce an indication of the target users' priorities.

CONTRACT DISTRIBUTION LIST
(Unclassified Technical Reports)

Director Advanced Research Projects Agency Attention: Program Management Office 1400 Wilson Boulevard Arlington, Virginia 22209	2 copies
Defense Technical Information Center Attention: DDC-TC Cameron Station Alexandria, Virginia 22314	12 copies

SUPPLEMENTAL DISTRIBUTION LIST
(Unclassified Technical Reports)

Department of Defense

Director
Defense Advanced Research
Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

Director
Defense Advanced Research
Projects Agency
Defense Sciences Office
System Sciences Division
1400 Wilson Boulevard
Arlington, VA 22209

Chairman
Department of Curriculum Development
National War College
Ft. McNair, 4th and P Streets, SW
Washington, DC 20319

Defense Intelligence School
ATTN: Professor Douglas E. Hunter
Washington, DC 20374

Department of the Navy

Office of Naval Research
ATTN: Dr. Martin Tolcott, Code 455
800 North Quincy Street
Arlington, VA 22217

Office of Naval Research
ATTN: Dr. Bert King, Code 452
800 North Quincy Street
Arlington, VA 22217

Office of Naval Research
ATTN: Mr. Randy Simpson, Code 431
800 North Quincy Street
Arlington, VA 22217

Dr. A. L. Slafkosky
Scientific Advisor
Commandant of the Marine Corps
(Code RD-1)
Washington, DC 20380

Dean of Research Administration
Naval Postgraduate School
ATTN: Patrick C. Parker
Monterey, CA 93940

Dr. Glen R. Algaier
Head
Command & Control
Information Processing Branch
Naval Ocean Systems Center
San Diego, CA 92152

Department of the Army

Deputy Under Secretary of the Army
(Operations Research)
The Pentagon, Room 2E621
Washington, DC 20310

Dr. Edgar M. Johnson
Organizations and Systems
Research Laboratory
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Ruth H. Phelps
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Dr. Harold F. O'Neil, Jr.
U.S. Army Research Institute
5001 Eisenhower Avenue
Alexandria, VA 22333

Chief, Studies and Analysis Office
Headquarters, Army Training and
Doctrine Command
Ft. Monroe, VA 23351

Department of the Air Force

Air Force Office of Scientific Research
Life Sciences Directorate
Building 410, Bolling AFB
Washington, DC 20332

Commandant
Air University
Maxwell AFB, AL 36112

Chief, Systems Effectiveness Branch
Human Engineering Division
ATTN: Dr. Donald A. Topmiller
Wright-Patterson AFB, OH 45433

Commander, Rome Air Development Center
ATTN: Mr. John Atkinson
Griffis AFB
Rome, NY 13440

Other Government Agencies

Central Intelligence Agency
ATTN: Dr. Austin W. Kibler (ORD)
Washington, DC 20505

Central Intelligence Agency
ATTN: Dr. Alison Fields (ORD)
Washington, DC 20505

Other Institutions

Institute for Defense Analyses
ATTN: Dr. Jesse Orlansky
400 Army Navy Drive
Arlington, VA 22202

Director, Social Science Research
Institute
University of Southern California
Los Angeles, CA 90007

Perceptronics, Incorporated
ATTN: Dr. Amos Freedy
6271 Variel Avenue
Woodland Hills, CA 91364

Department of Psychology
ATTN: Dr. Lawrence D. Phillips
Brunel University
Uxbridge, Middlesex UB8 3PH
ENGLAND

Decision Research
1201 Oak Street
Eugene, OR 97401

School of Engineering and
Applied Science
ATTN: Dr. Andrew P. Sage
University of Virginia
Charlottesville, VA 22901

Harvard Business School
ATTN: Professor Howard Raiffa
Morgan 302
Harvard University
Cambridge, MA 02163

Department of Psychology
ATTN: Dr. Charles Gettys
Dale Hall Tower
University of Oklahoma
455 West Lindsey
Norman, OK 73069

Institute Of Behavioral Science #3
ATTN: Dr. Kenneth Hammond
Room 201
University of Colorado
Boulder, CO 80309